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U.S. NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE, PENNSYLVANIA

98500

Aviation Medical Acceleration Laboratory

**Pilot's Ability to Actuate Ejection Controls;
final report concerning**

**Bureau of Aeronautics
TED ADC AE 5205
(NM 15 01 12.3)**

U. S. NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE, PENNSYLVANIA

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5 Feb 1959

From: Commanding Officer, U. S. Naval Air Development Center
To: Chief, Bureau of Aeronautics (AE-52)

Subj: TED ADC AE 5205 (NM 15 01 12.3) "Pilot's Ability to Actuate Ejection Controls"; final report concerning

Ref:

- (a) BuAer ltr Aer-AE-5211/136 of 9 Aug 1957
- (b) NADC ltr rpt TED ADC AE 6303 ser 10467 of 3 Nov 1953
- (c) NADC ltr rpt TED ADC AE 6303.1 ser 9393 of 16 Sept 1954
- (d) NADC ltr rpt TED ADC AE 6303.1 ser 9341 of 24 Aug 1955
- (e) NADC ltr rpt TED ADC AE 6303.1 ser 2625 of 29 Mar 1957
- (f) NADC ltr rpt TED ADC AE 6303.1 ser 2682 of 1 Apr 1957
- (g) NADC ltr rpt TED ADC AE 5205 ser 3585 of 5 May 1958

Encl:

- (1) McDonnell-Stanley ejection seat equipped with the torso-head restraint system installed in the gondola of the AMAL centrifuge.
- (2) Physiological acceleration vectors along the anatomical body axes.
- (3) Time required by subjects wearing summer flight suit and Mark V exposure suit to operate ejection controls of the McDonnell-Stanley ejection seat with torso-head restraint system.
- (4) Martin-Baker G-5 ejection seat with integrated harness installed in the gondola of the centrifuge.
- (5) Time required by subjects, wearing summer flight suits, to operate ejection controls of the Martin-Baker ejection seat equipped with integrated harness.
- (6) Average maximum G level at which subjects, wearing the lightweight full pressure suits, not inflated, successfully operated ejection controls of the Martin-Baker G-5 seat.
- (7) Average maximum G level at which a subject, wearing the lightweight full pressure suits, inflated, successfully operated ejection controls of the Martin-Baker G-5 seat.
- (8) Subject, wearing the Arrowhead full pressure flight suit, inflated, attempting to pull the D-ring of the Martin-Baker G-5 ejection seat.
- (9) Subject, wearing the Goodrich full pressure flight suit, inflated, attempting to pull the D-ring of the Martin-Baker G-5 ejection seat.
- (10) Subject, wearing the Arrowhead full pressure flight suit, inflated, attempting to reach the canopy jettison override control of the Martin-Baker G-5 ejection seat.

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- (11) Subject wearing the Goodrich full pressure flight suit inflated attempting to reach the canopy jettison override control of the Martin-Baker G-5 ejection seat.
- (12) Average maximum G level at which subjects wearing summer flight suits successfully operated ejection control after pulling canopy jettison override control of the Martin-Baker G-5 seat.

1. As directed by reference (a) an investigation was carried out at the Aviation Medical Acceleration Laboratory (AMAL) to study the effects of acceleration on the ability of pilots to operate ejection controls. This letter report constitutes the final report of this investigation. Earlier work performed at this laboratory related to this investigation was reported in references (b) through (g).

2. The purpose of the present study was two-fold. The first part was to determine the effects of acceleration on a pilot's ability to actuate the ejection controls of two makes of ejection seats, the McDonnell-Stanley ejection seat equipped with an experimental torso-head restraint system and the Martin-Baker G-5 ejection seat equipped with the integrated harness restraint system. The second purpose was to determine the degree to which the Mark V exposure flight suit and Mark IV (Goodrich) and the AX-83 (Arrowhead) lightweight full pressure flight suit impeded a pilot in the actuation of the ejection controls when compared to his performance while wearing the summer flight suit.

3. The McDonnell-Stanley Seat. Enclosure (1) shows the McDonnell-Stanley seat installed in the centrifuge gondola with a subject restrained by the torso-head restraint system. The face curtain required a 15-pound load to detent and a 20-pound load to fire, and the D-ring required a 28-pound load to detent and a 35-pound load to fire. The ejection seat mockup consisted of a throttle handle, a control stick, rudder pedals, and two signal lights, one red and one green. These signal lights were mounted 30 inches in front of the subject with the red light above the green.

4. The ejection procedures performed by the subjects were as follows: The subject sat in the seat with his feet on the rudder pedals, his left hand on the throttle handle and his right hand on the stick. Whenever the red signal light went on the subject removed his hands from the throttle handle and the control stick and pulled the face curtain. If the green light went on, the response was the same except that the D-ring was pulled rather than the face curtain.

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5. Both ejection procedures were performed under four orientations of acceleration (G). The four orientations of G applied to the subject are shown in enclosure (2). The range of acceleration used for the positive and the transverse chest-to-back orientations was 1 - 6 G, the range for the transverse back-to-chest orientation was 1 - 5 G, and the range for the lateral orientation was 1 - 4 G. The subject received no previous information prior to the occurrence of the run as to the orientation or degree of acceleration or the ejection control to use. These conditions were presented to the subject in a random order. The acceleration-duration pattern used has a rise time of 5 seconds, a maximum of 10 seconds and a decay time of 8 seconds. However, actuation of either ejection control before the regular termination of the run stopped the centrifuge. The ability to stop the centrifuge by pulling the ejection control provided the subject with motivation to complete the ejection procedure as quickly as possible. The signal to eject, the onset of either the red or the green signal light, was given within the first 3 seconds at peak G.

6. Records were obtained of the time required for the subject to remove his hands from the stick and the throttle and to pull the D-ring or face curtain. To obtain these records, the throttle handle, control stick, face curtain, and D-ring were equipped with microswitches which were tripped as the subject went through the ejection procedures. The microswitches activated the galvanometers on a Heiland recorder; the time measures for each run were then obtained from the Heiland record.

7. Four subjects each made two series of runs in this investigation. For the first series of runs the subjects wore a summer flight suit, a helmet, and a Z-3 G-suit; for the second series of runs the subjects replaced the summer flight suit with the Mark V exposure suit. The order of presentation of the accelerations and ejection conditions was the same for both series of runs.

8. The results of the runs with the McDonnell-Stanley seat are shown in enclosure (3). The average times required by the subject to eject while wearing each of the flight suits is shown in bar graph form for each condition of acceleration and each ejection control. Whenever the data are other than the average of four subjects the number of subjects represented by the average is given in the bar of the graph. Each "X" on the top of a bar signifies that one subject failed to operate the ejection control during the 10 seconds that he was held at peak acceleration.

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9. It may be concluded from these results that under the conditions of acceleration used, the D-ring is more accessible than the face curtain, and that the weight of the exposure suit offered some obstruction to movements by the subject in the direction opposite to the direction of the acceleration.

10. Comments by the subjects revealed a number of unsatisfactory features in the McDonnell-Stanley seat and torso-head restraint system,

a. The subjects received bruises from two sources: the upper cross-member of the seat back-pan protruded sufficiently to be pressed forcefully into the back of the neck during the centrifuge runs, and the fixtures anchoring the chest strap to the back-pan dug into the postero-medial area of the arm or side of the chest during lateral accelerations.

b. The wide wrap-around design of the face curtain handle is such that the subjects brought their hands up over their shoulders and grasped the sides of the face curtain handle. When the curtain was pulled out to the end of its travel with the hands in this position, the wrists were forcefully abducted laterally causing a sharp pain. This pain is due to sudden forceful compression of the joint that could result in a serious injury during a vigorous, frantic pull.

c. During lateral acceleration runs the head restraint system became jammed so that the subject's head was locked in a position of 30° tilt.

d. The subjects reported that the parachute back-pack was an extremely poor back rest and quite uncomfortable.

11. The Martin-Baker G-5 Seat. The Martin-Baker G-5 ejection seat equipped with the integrated harness was installed in the centrifuge gondola as shown in enclosure (4). The face curtain required a 26-pound load to detent and a 24-pound load to fire. The force required to operate the D-ring could not be determined with any specificity. The connecting cable to the D-ring continued to foul more and more often during the course of the investigation, and, as a result, no single value for the force required for the operation of the D-ring can be given. In other respects the installation for the Martin-Baker seat was the same as that described in paragraph 3 for the McDonnell-Stanley seat.

12. The ejection procedures performed by the subjects were the same as those described in paragraph 4.

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13. The conditions of acceleration and procedures were the same as those described in paragraph 5.

14. The records obtained were the same as those described in paragraph 6.

15. The same subjects were used as before. Four subjects made the first series of runs. Each wore a summer flight suit as described in paragraph 7. Three subjects wearing the Goodrich suit not inflated made a second series of runs. One subject wearing the Arrowhead suit, not inflated, repeated this series of runs. This same subject then made a series of runs in each full pressure suit inflated to 2.2 pounds per square inch.

16. The results of the runs made with the subjects wearing the summer flight suit are shown in enclosure (5). The average times required by the four subjects to eject while wearing the summer flight suits are shown for each condition of acceleration and each ejection control. As before, the averages are for four subjects except where noted in the bar of the graph, and an "X" signifies a failure of a subject to eject.

17. It may be concluded from these data that little difference exists between the accessibility of the two ejection controls under positive and transverse chest-to-back acceleration which forced the subject down and back into the seat. But under transverse back-to-chest and lateral accelerations, where the subject was thrown against the harness, the accessibility of the D-ring was markedly decreased.

18. There was no apparent difference in the obstruction offered by the Goodrich and Arrowhead full pressure suits when they were not inflated. For this reason, the data on the two kinds of suits are combined in enclosure (6). The average maximum G level at which the subjects were able to operate the ejection controls is shown for both controls under each condition of acceleration.

19. It may be concluded from these data that the full pressure suit reduces the probability that a pilot will be able to eject successfully in a Martin-Baker seat equipped with the integrated harness.

20. The average maximum G levels at which the subject wearing the full pressure suit inflated was able to reach and pull out the ejection controls are shown in enclosure (7). It should be noted that acceleration helped as well as hindered the subject to operate the ejection controls. The D-ring was beyond

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the reach of the subject at the 1 G level for all orientations of acceleration but when at higher levels the subject was assisted by the acceleration in three of the four orientations studied. Enclosure (8) and (9) are photographs of the subject attempting to reach the D-ring at 1 G positive acceleration. The canopy jettison override handle was completely beyond the reach of the subject in an inflated full pressure suit under all conditions of acceleration. Enclosures (10) and (11) show the subject wearing the Goodrich suit and the Arrowhead suit attempting to reach the canopy jettison override handle.

21. It may be concluded from these data that inflation of the full pressure suit further reduces the probability of a successful ejection. The Goodrich is the more flexible of the two suits.

22. A cursory check of the accessibility of the canopy jettison override control handle was made with two subjects wearing the summer flight suit. The results of these series of runs are shown in enclosure (12). When the orientation of the direction of acceleration is such as to throw the subject out of the seat the subject's ability to reach the canopy jettison override control handle is reduced.

23. It may be concluded on the basis of these data that the canopy jettison override control handle should be relocated to make it more easily accessible to the pilot wearing any type of flight clothing under any acceleration.

24. Comments by the subjects revealed a number of unsatisfactory features of the Martin-Baker seat and the integrated harness system.

a. The two rubber bumpers on the lower side of the face curtain caught on the trailing edge of the full pressure suit sun visor when the visor was in the "up" position.

b. The shoulder harness release control was inadvertently operated a number of times during the course of the acceleration runs. This occurred when the subject's leg was thrown against the release handle or when the cuff of the full pressure suit sleeve caught on it. The subject was thrown forward out of the seat.

c. The envelope within which the body may move or be thrown around is very great. This lack of restraint is the primary reason for the inability of the subjects to reach the ejection controls. The one point suspension system

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of the shoulder straps permitted excessive lateral torso movement as well as forward movement of the shoulders. The long radius of the lap belt connections allows the body to swing up out of the seat under transverse back-to-chest acceleration. Neither the lap belt connections nor the shoulder connections are designed to allow the subject to be adequately restrained,

d. The Rocket Jet Engineering Corporation fitting (Part No. 109000 E) that connected the lap belt to the integrated harness inadvertently opened on at least two occasions. A check on this point with the Naval Aviation Safety Center revealed two functional failures of this type of fitting during crashes.

e. The subjects reported a complete lack of lower back support and general discomfort after a series of centrifuge runs over a period of 30 minutes.

25. Comments by the subjects revealed a number of minor differences between the two full pressure suits which should be corrected as well as two minor faults common to both.

a. The ventilation rate of the suits was inadequate when the subject was under stress. This led to profuse sweating and soaking of the undergarments which could not be prevented by increasing the ventilatory rate to the highest setting.

b. Due to the absence of any protection for the trailing edge of the visor while in the up position, repeated pulling of the face curtain over the helmet eventually resulted in failure of the sun visor pivot connections.

c. The Goodrich Mark IV suit was considered superior to the Arrowhead AE-83 suit in the following respects:

(1) It is more comfortable to wear, due mainly to the increased comfort across the shoulders.

(2) The neutral head position with suit inflated is more comfortable. It is erect rather than pitched forward as in the Arrowhead.

(3) Sizing is easier and readjustment is simpler.

d. The Arrowhead AE-83 suit was considered superior to the Goodrich Mark IV suit in the following respects:

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(1) Head movement was easier than in the Goodrich suit.

(2) The one-layer glove was easier to don, in that fingers, if turned inside-out on removal, can easily be returned to their normal inside-in position prior to putting them on again.

(3) The suit closure is simpler because of the one large spiral zipper which is more accessible to the individual donning the suit than the zippers on the Goodrich suit.

(4) The "Iron Age" boots supplied with the Arrowhead suit seem to be superior to those supplied with the Goodrich suit in that they are a more rugged boot which will give more support to the ankles on parachute landings and are more rugged for hiking.

26. The results of this study show that a pilot, under conditions of acceleration similar to those which might occur in uncontrolled flight, may not be able to reach either the face curtain or the D-ring. Any encumbrances on the pilot such as an exposure suit or a full pressure suit will decrease the probability of his successful ejection. Failure of the canopy to jettison upon operation of the ejection control and the subsequent requirement for use of the emergency actuation control will further decrease this probability, particularly if he is wearing an inflated full pressure suit. It should be pointed out that these results occurred even though the subjects in this study were restrained to the maximum degree offered by the harnesses used. As pointed out above, the integrated harness used with the Martin-Baker seat allowed the subject to be thrown about excessively even though the shoulder harness was maximally retracted and the lap belt was maximally tightened.

27. In view of these results it is recommended that any attempt to rectify this inability of pilots to operate ejection controls under acceleration should be in the direction of the redesign and development of the ejection seat, ejection controls, and restraint system, as the development of the protective flight clothing has apparently reached the point of diminishing returns. Specifically, it is recommended that:

a. A single type of ejection control located on either side of the seat bucket or on the arm rests be developed.

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b. A six-point restraint system, either side of the shoulder, chest, and lap, be developed.

c. A head restraint system be developed that aligns the head with the torso, in preparation for ejection by means of attachments to the torso rather than to the ejection seat.

d. Automatic as well as manual operation of the restraint system to retract the pilot into the correct posture for ejection be developed.

e. A seat be designed with the comfort of the pilot in mind, a seat that can be adjusted to the body dimensions of the pilot and support his body properly, thus enabling him to perform his mission more efficiently.

28. This report was prepared by J.H. Hill of the Psychology Division and M.G. Webb, LCDR, MC, USN, with J.L. Brown as consultant, and approved by Dr. James D. Hardy, Research Director, Aviation Medical Acceleration Laboratory.



F. K. SMITH

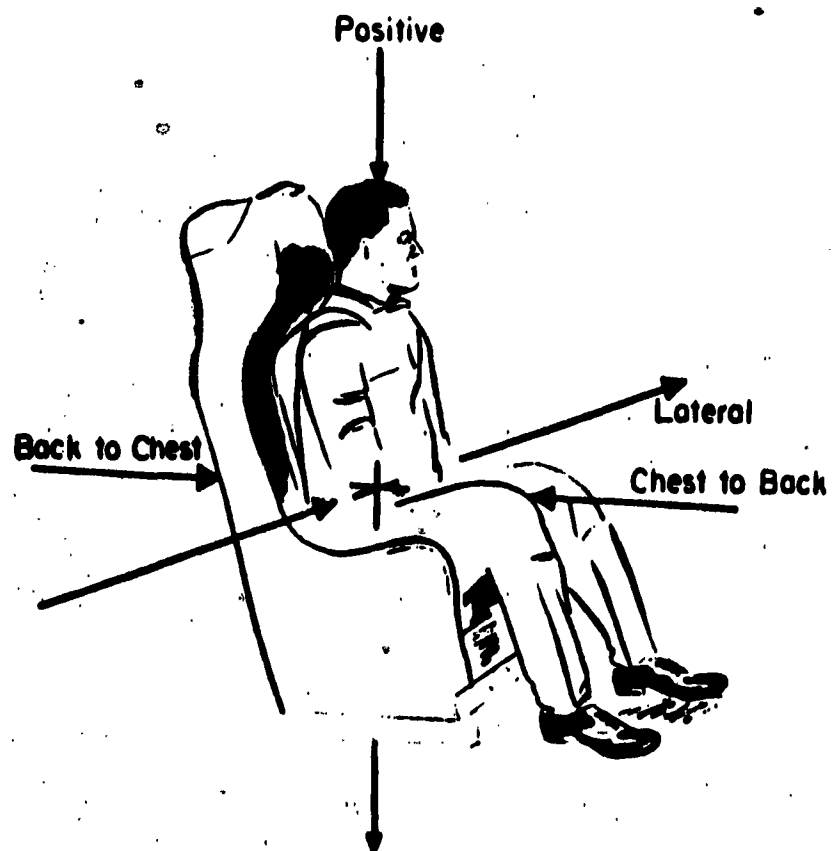
By direction

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CO, NARF
CDR, NADMC



The McDonnell-Stanley ejection seat equipped with the torso-head restraint system installed in the gondola of the AMAL centrifuge.

ENCLOSURE (1)

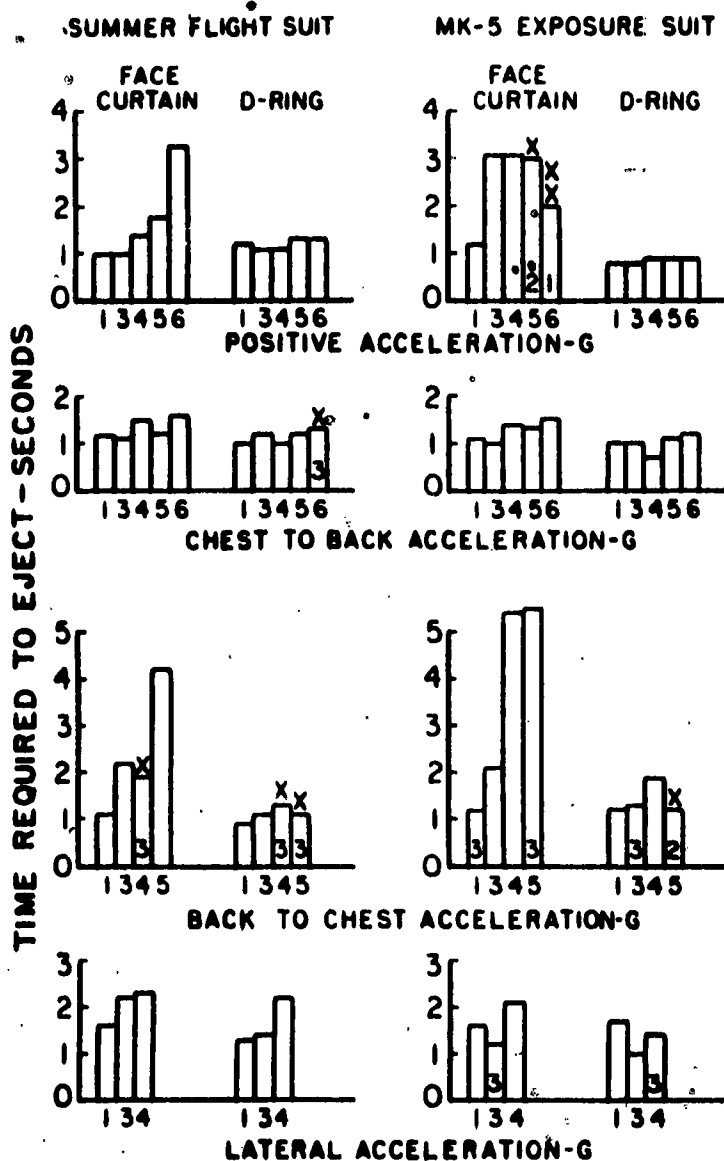


Physiological acceleration vectors along the anatomical body axes.
Vectors indicate direction the pilot is forced relative to the ejection
seat.

ENCLOSURE (2)

McDONNELL-STANLEY EJECTION SEAT WITH TORSO-HEAD RESTRAINT SYSTEM

*Except as noted N = 4 X = Unsuccessful Ejection



Time required by subjects, wearing the summer flight suit and Mark V exposure suit, to operate ejection controls of the McDonnell-Stanley ejection seat with torso-head restraint system.

ENCLOSURE (3)

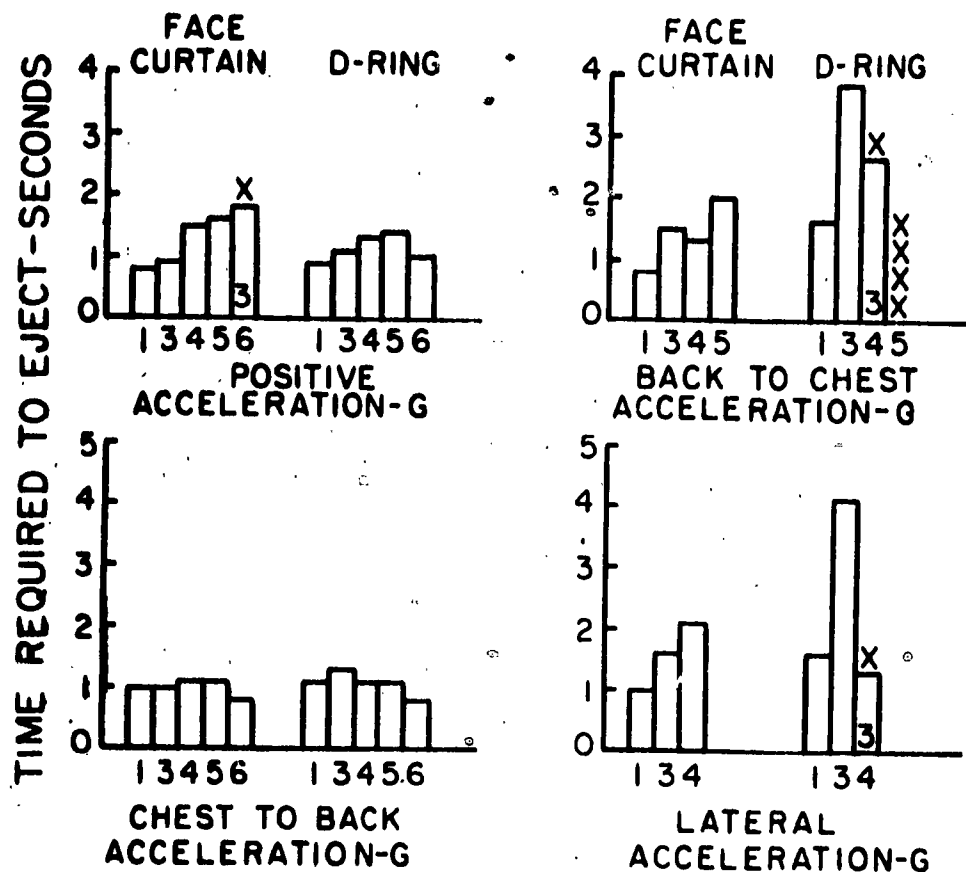


The Martin-Baker G-5 ejection seat with integrated harness installed in the gondola of the centrifuge.

ENCLOSURE (4)

**MARTIN-BAKER EJECTION SEAT (MB, G-5)
WITH INTEGRATED HARNESS
SUMMER FLIGHT SUIT
N = 4**

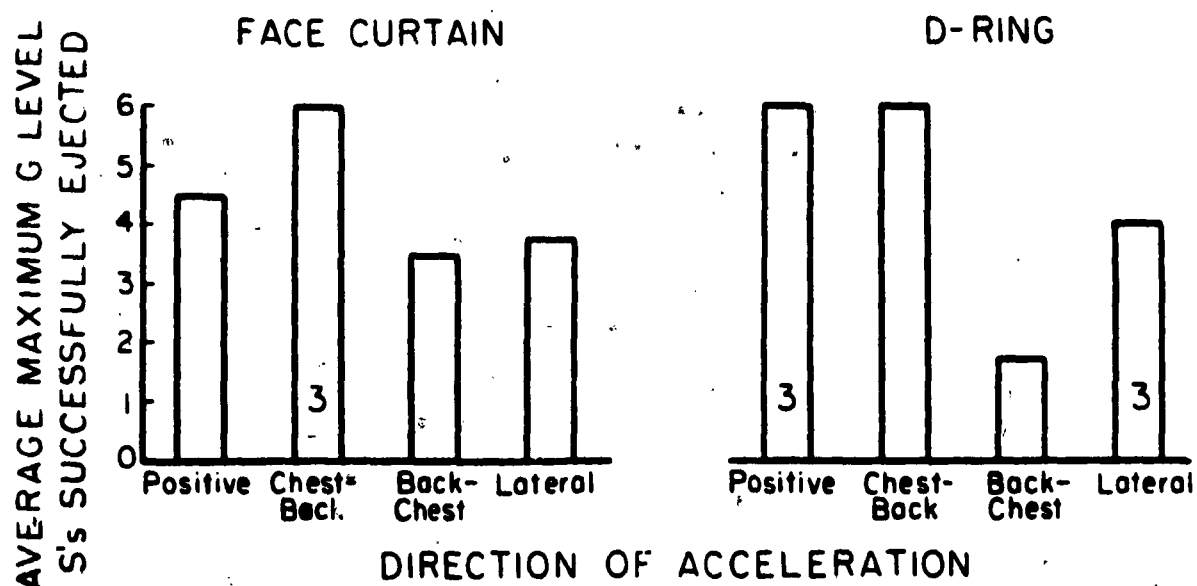
X = Unsuccessful Ejection



Time: required by subjects, wearing summer flight suits, to operate ejection controls of the Martin-Baker ejection seat equipped with integrated harness.

ENCLOSURE (5)

LIGHT WEIGHT FULL PRESSURE SUITS NOT INFLATED-MB,G-5 SEAT
N=4

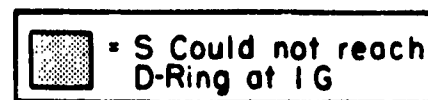
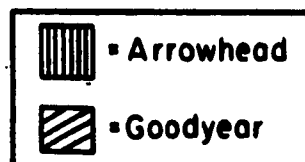


Average maximum G level at which subjects, wearing the lightweight full pressure suits, not inflated, successfully operated ejection controls of the Martin-Baker G-5 seat.

ENCLOSURE (6)

LIGHTWEIGHT FULL PRESSURE SUITS INFLATED (2.2 psi)-MB, G-5 SEAT

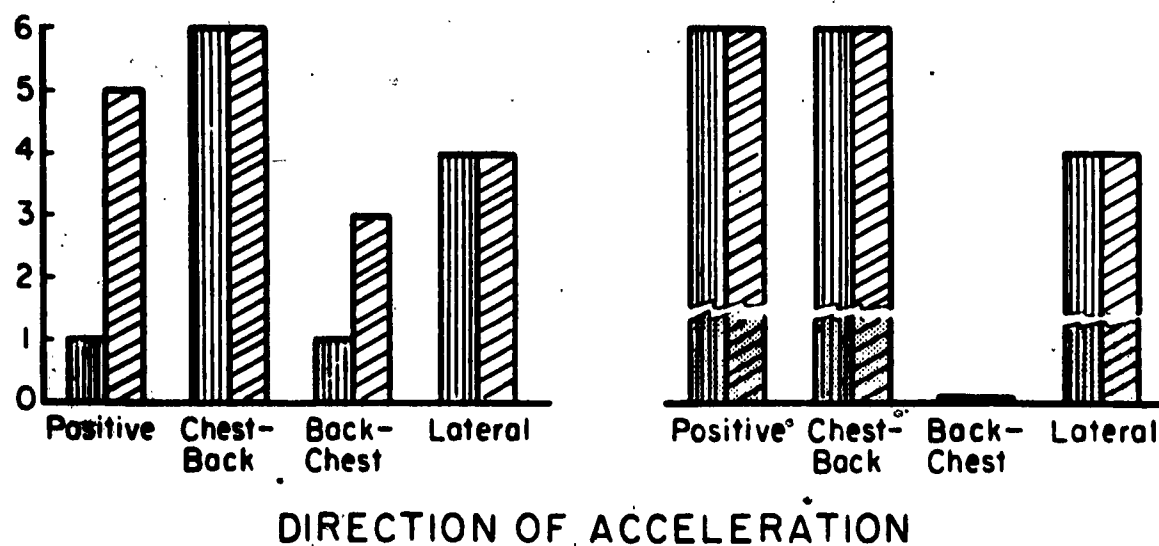
N=1



AVERAGE MAXIMUM G LEVEL
S SUCCESSFULLY EJECTED

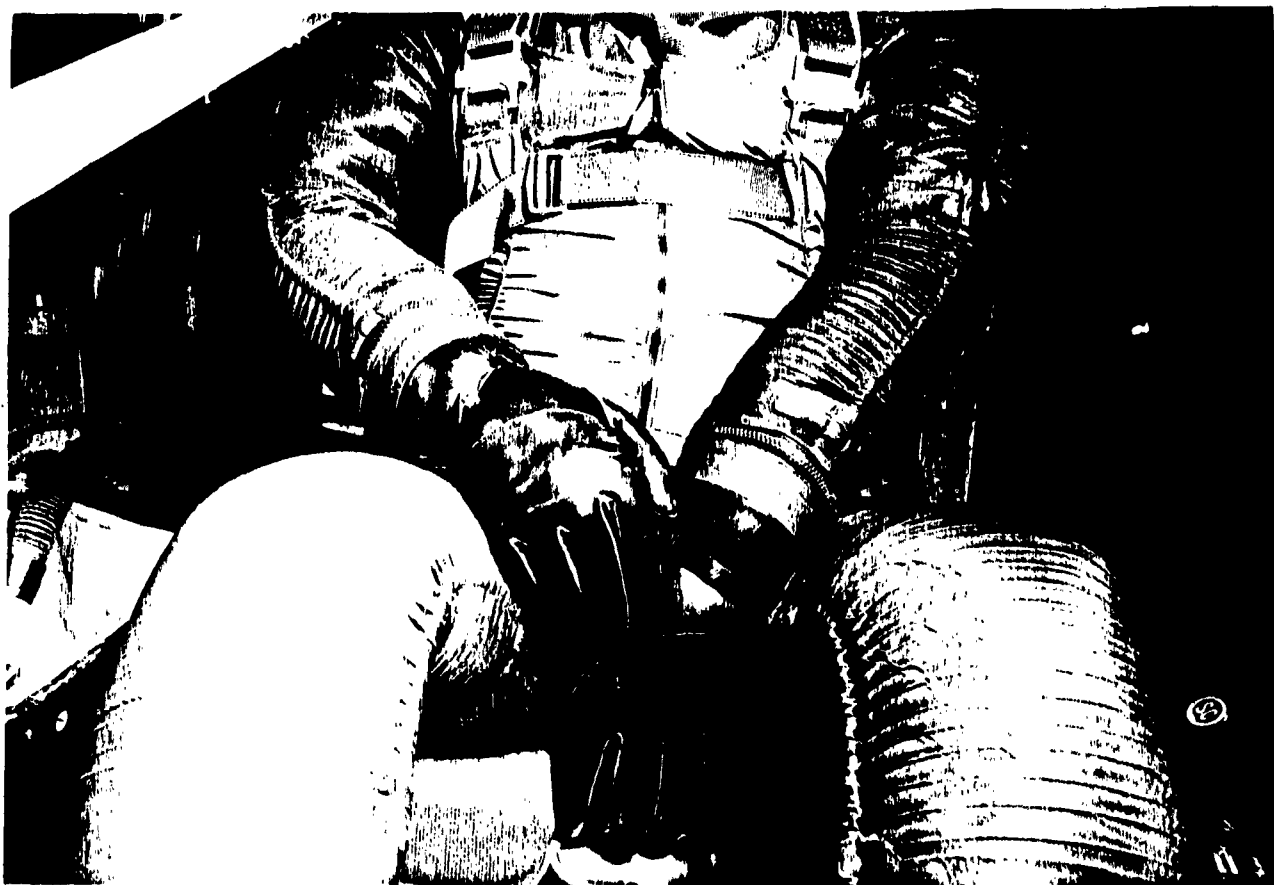
FACE CURTAIN

D-RING



Average maximum G level at which a subject, wearing the lightweight full pressure suits, inflated, successfully operated ejection controls of the Martin-Baker G-5 seat.

ENCLOSURE (7)



Subject, wearing the Arrowhead full pressure flight suit, inflated, attempting to pull the D-ring of the Martin-Baker G-5 ejection seat.

ENCLOSURE (8)



Subject, wearing the Goodrich full pressure flight suit, inflated, attempting to pull the D-ring of the Martin-Baker G-5 ejection seat.

ENCLOSURE (9)



Subject, wearing the Arrowhead full pressure flight suit, inflated, attempting to reach the canopy jettison override control of the Martin-Baker G-5 ejection seat.

ENCLOSURE (10)

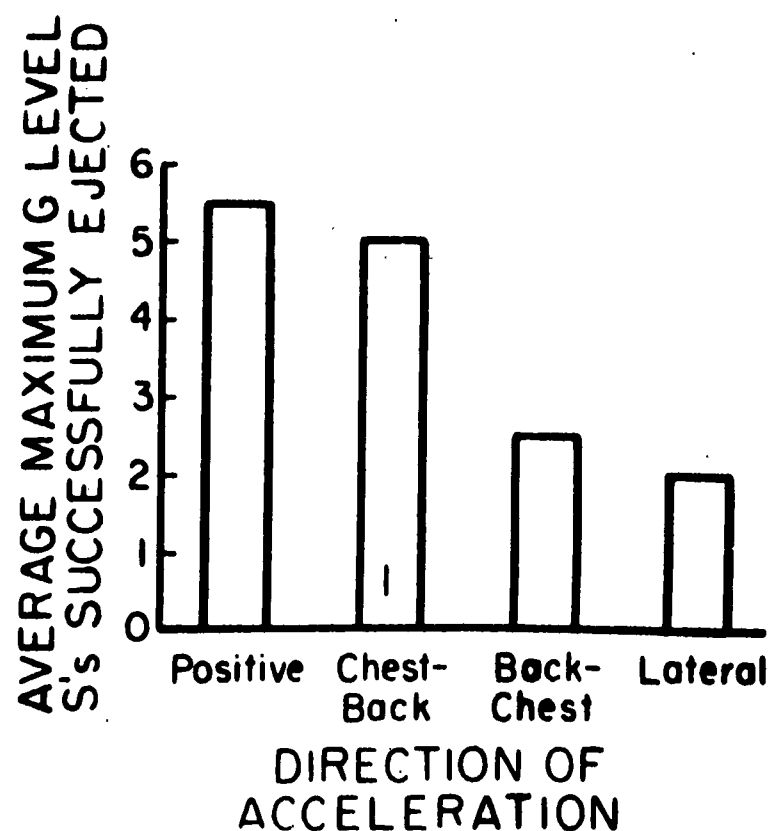


Subject, wearing the Goodrich full pressure flight suit, inflated, attempting to reach the canopy jettison override control of the Martin-Baker G-5 ejection seat.

ENCLOSURE (11)

OPERATION OF CANOPY JETTISON
OVERRIDE CONTROL MB, G-5 SEAT
SUMMER FLIGHT SUIT

N = 2



Average maximum G level at which subjects, wearing summer flight suits, successfully operated ejection control after pulling canopy jettison override control of the Martin-Baker G-5 seat.

ENCLOSURE (12)